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WATER, THE SOIL AND THE PLANT*

THAT the ability of soils to maintain a suitable supply of water for growing crops is fundamental to agricultural practice is self-evident. A large proportion of the cultivated soil of the world receives too much or too little water to permit optimal crop growth. Cultural practice, crop selection, and, above all, the major engineering operations involved in drainage or irrigation have done much to modify the unsuitability of natural conditions. Yet, even where soil and climatic conditions offer no serious difficulties to crop production, suitable operational practice is still an important factor in ensuring that the crop actually gets the quantity of water it needs at the time when this is most necessary. It has been said that, even in this country, food production suffers more from inadequacy of water supply to growing crops than from any shortage or unsuitability of plant nutrients for which the fertiliser industry so effectively caters.

Problems of the supply of soil-water, as distinct from its utilisation by the crop, largely centre around physical conditions in soils. It would appear that scientific investigations of soil physics have been less inviting than those of the chemistry of soil to research workers. They are perhaps productive of less attractive results, but they are certainly less capable of commercial exploitation.

It is a standing tribute to those who from time to time have shaped the destinies of the Rothamsted Experimental Station that for many years soil physics has been established and maintained as a subject of extensive investigation. In recent years the progressive mechanisation of farming, and especially modern innovations in mechanical tillage, have stimulated a deeper interest in the physical aspects of soil science and have gone far towards ensuring that this important branch of agricultural science should receive its due consideration. It is significant, perhaps, that the current period of awakened interest in the physical problems of soil coincides with an almost complete reversal of traditional opinion on such subjects as the movement of water through soil and the rôle of certain tillage operations in the maintenance of the supply of water to crops.

* Abstracted from the section on *Soils and Fertilizers* by A.G. Pollard. Reports of the Chemical Society of Chemical Industry on the Progress of Applied Chemistry—Vol. XXVII.

In providing a scientific basis to proven agricultural practice (and this is still the major preoccupation of more than a few agricultural scientists) there is inevitably a need for a suitable system of measurement of relevant phenomena—a "yard-stick" to which results of investigations may be referred, or by which the nature and size of the problem may be assessed. In researches on soil—water relationships it has long been apparent that the mere measurement of the amount of water in soil at different times or depths below surface did not wholly portray and certainly failed to explain numerous problems of soil-water supply in relation to cropping practice. The search for a "yard-stick" has progressed slowly and at times with considerable difficulty. That a variety of physical or physico-chemical factors in soil were concerned with its water-supplying power was early apparent, and, as a consequence numerous physical or mechanical properties or characteristics of soil have been utilised, in turn, as a basis for describing, explaining, or predicting its water status. Older concepts of capillary movement of water through soil and the adoption of relevant physical measurements gradually gave place to the more serviceable "single value" factors for describing this aspect of the physics of soils. More recently the mental picture of the transfer of water from soil to plant has undergone further modification. No longer is the emphasis placed on the movement of water through soil towards roots. Rather is it stressed that the roots range towards the water source, and the physical problem involved is the relative ease with which the soil yields up its water to roots in contact with it. The measurement of this in terms of the suction force of soils is perhaps the outstanding development in the study of soil physics as related to water supply to the growing plant. It represents, too, a definite step towards the approximation of physical measurements in soil and the mechanism of water intake by plants. The plant physiologist is obviously concerned here, and it may well be that the next stage of advancement in the appreciation and clarification of soil—water—plant relationships will depend in no small measure on the closer application of plant physiological observations to the problem in hand.

Meanwhile investigators of these problems show no incautious desire to discard previous methods of physical measurement merely because they were initiated under earlier concepts of soil—water relationships. Many of these measurements though primarily concerned with the physical activities of water in soil have a secondary value in characterising soil properties of interest for other reasons, and should not therefore be abandoned until their usefulness has been carefully examined. Moreover, with the development of new ideas in soil physics, many kinds of physical measurements in soils do not necessarily become obsolete, but merely acquire a new significance.

Recent publications include many relating to improvements in technique of, or in the interpretation of results obtained by, old-standing methods and to the correlation of data obtained by a diversity of physical measurements as well as recording the perfection of more recently established experimental processes. The necessity of making numerous and frequent observations in many water problems has tended to bring forward simple and/or rapid methods of measurement for laboratory and especially for field use.

TWO NEW INSECTICIDES—DDT AND 666

BY

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For many years both chemists and entomologists have searched for a substance, highly toxic to insects but harmless alike to plants, man and domestic animals, which is cheap to use and easy to apply. Until recently few if any known substances even approached such perfection. The efforts of workers in this field have now met with a greater measure of success than the most sanguine predictions.

Extensive publicity has been given for some time both in the press and in technical journals in Britain and the United States to a remarkable new insecticide. This is known as DDT, a convenient abbreviation for the compound dichlorodiphenyltrichloroethane. It is made by the interaction of chloral hydrate and monochlorobenzene in the presence of concentrated sulphuric acid, from which it is obtained in the form of fine, white crystals, insoluble in water. Various isomers are known and the most active of these appears to be para-para-dichlorodiphenyltrichloroethane.

This substance was first synthesized in Germany by Othmar Ziedler in 1874, but it was not until 1939 that its insecticidal properties were discovered. It was first developed as an insecticide in Switzerland, and much subsequent work has been carried out in Britain and the United States and elsewhere. It has proved to be unusually effective against human lice, house-flies and mosquitoes, but has not yet come into use for the control of crop pests. Whether DDT has a future as an agricultural insecticide depends on the development of methods of using it as an effective, safe and cheap dust or spray in the field.

A rapidly growing literature already exists on the use of DDT. The results of trials on a large scale against mosquitoes and other insects of medical importance have been reported from various parts of the world. Much of this work has been carried out by the military authorities often in actual theatres of war, many of them in the tropics. Recent information is summarized in the

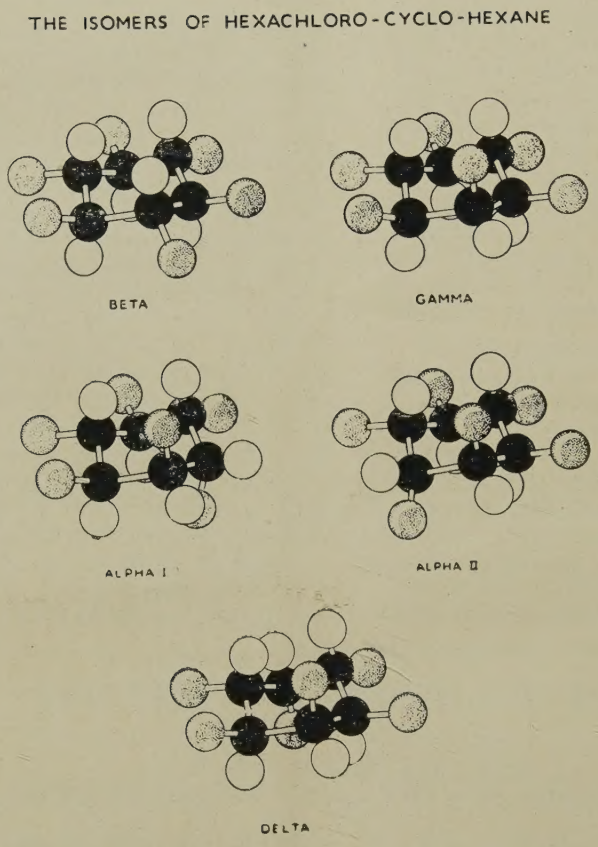

Fig. 1—Diagrammatic representation of isomers of hexachlorocyclohexane. In each molecule carbon atoms are represented by black circles, hydrogen atoms by white circles and chlorine atoms by stippled circles. (After Slade).

mimeographed Monthly News-Letter on Insecticides published by the Insecticide Development Panel of the British Ministry of Production.

In the United States especially this insecticide has been tested on a very extensive scale against a wide range of agricultural and veterinary pests. A notable summary is the symposium of papers by Annand *et al.* (1944) on the comprehensive series of tests carried out by the Bureau of Entomology and Plant Quarantine of the U.S. Department of Agriculture. In summing up the results of recent work, the view is expressed in the United States that, while DDT is unquestionably the most promising insecticide so far developed, it is still in the experimental stage and is not yet safe for general use.

More recently another new and possibly even more promising insecticide than DDT has been discovered. This is known as 666, a convenient abbreviation for the compound hexachlorocyclohexane or benzene hexachloride. It is made by chlorinating benzene in the presence of light and crystallizing the resulting product from benzene. Well-defined, colourless crystals are formed, practically insoluble in water.

This substance was apparently first prepared by Michael Faraday as long ago as 1825. It was only as recently as 1942 that British research revealed its outstanding insecticidal properties. Hexachlorocyclohexane is known to exist in a number of different isomers (see Fig. 1), which vary greatly in their toxicity to insects. In 1943 the gamma isomer was found to be extremely toxic to insects, this isomer being present to the extent of 10 to 12 per cent. in the mixture of isomers in crude hexachlorocyclohexane. The insecticidal action of 666 is therefore to be attributed almost entirely to the presence of this isomer, which has been given the abbreviated name of gammexane. So toxic is the gamma isomer of 666 that it has shown marked superiority to DDT in comparative tests using such insects as house-flies, mosquito larvae and grain weevils. An interesting account of the development of 666 is given by Slade (1945), and much recent information is summarized in the Monthly News-Letter on Insecticides of the British Ministry of Production, to which reference has already been made.

Very little is known concerning the mode of action of chemotherapeutic agents upon the life processes of the cell. In his paper, Slade (*loc. cit.*) presents an interesting and highly speculative hypothesis to explain the possible mode of action of such insecticides as 666 and DDT. Dr. Slade points out that in the sulphonamide drugs the active chemotherapeutic agent is known to masquerade as a molecule which is essential for the life of the cell. In other words B-aminobenzene sulphonamide reacts where B-aminobenzoic acid should have been in a normal cell reaction. This is then unable to perform the next function of normal cell life so that the cell dies.

Hexahydroxycyclohexane or inositol is a metabolite found widespread in many types of cells. Dr. Slade suggests, on the analogy of the sulphonamides, that a molecule similar to inositol should be capable of being taken up by an organism and gaining access to its cells. Isomers of hexachlorocyclohexane are molecularly similar to inositol, and the gamma isomer is very similar indeed to mesoinositol, which forms part of the vitamin B complex. Thus it is possible that the gamma isomer of 666 is absorbed by the insect and gains access to its cells, where a vital reaction is blocked and the insect killed. Similarly DDT may act in much the same way by blocking the normal cell process dependent upon inositol or some completely different vital reaction.

Some remarkable advances have been made in recent years by British research in chemotherapy. The discovery of penicillin and a whole range of similar substances has revealed wonderful possibilities for the cure of human and animal diseases. The discovery of DDT and 666 may presage the development of even more effective substances and opens up similar amazing possibilities for the control of insect pests.

References

Annand, P. N. *et al.* (1944) Tests conducted by the Bureau of Entomology and Plant Quarantine to appraise the usefulness of DDT as an insecticide. *Jour. Econ. Ent.*, 37: 125-159.

Slade, R. (1945) The gamma isomer of hexachlorocyclohexane (gammexane), an insecticide with outstanding properties.

Hurter Memorial Lecture to Liverpool branch of the Society of Chemical Industry (mimeographed).

MAINTENANCE OF SOIL FERTILITY IN NATIVE MAIZE AREAS IN NORTHERN RHODESIA

According to the 1943 *Ann. Rept.* of the *Dept. of Agric., Northern Rhodesia*, the fertility of the economically important and irreplaceable Native maize areas is still declining, though the rate of retrogression has been retarded by the provision of soil conservation works. That essential preliminary to the general introduction of improvements—conclusive demonstration—has been accomplished. The extent of the transformation which could be effected within a short period was amply proved during the year. There was fairly conclusive evidence that the average yield of Native maize did not exceed 2¾ bags per acre. On seven gardens cultivated by "village demonstrators" the average yield was 5¼ bags per acre, which approximated closely to the yield on European farms. The demonstration gardens were widely scattered and were representative of the maize area in that they comprised a fairly complete range of soils in varying degrees of exhaustion. The highest yield obtained was 13 bags per acre (77 bags from 6 acres) from a garden which produced only 2½ bags per acre before being taken over two years ago. The lowest was 3 bags per acre from a garden which was completely worn out in 1941.—(*Soils and Fertilizers*, VII, 4, 1944.)

THE MOISTURE PROFILE IN SOME TRINIDAD FOREST AND CACAO SOILS

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(I) Introduction

THE following article describes an investigation into the distribution and fluctuation of water within the profile for a range of soil-types occurring in Trinidad, and discusses the implications of the results. The field work was initiated in March, 1940, by one of us (E.M.C.) and continued during the ensuing 14 months. The procedure was as follows. At each site representing a soil-type, a six-foot pit was dug once every other month, a fresh spot being selected on each occasion. All the spots at any one site fell within an area of about half-an-acre. The profile was sampled on each visit at regular depths for soil moisture content, the samples being procured with a trowel and put at once into tins provided with air-tight lids for transportation to the laboratory. Moisture determinations were made by drying and weighing, the results being expressed as percentages on oven-dry weight of soil.

When sufficient bi-monthly data had accumulated, it was sought to discover how near the determined values for soil moisture content had approached saturation point during the wet season and how near to wilting point in the dry season by comparing the data with physical soil constants determined on specials samples representing the different profile layers.

Some peculiar features were revealed by certain of the sets of data, so that it was decided to resample the site profiles by means of a constant volume cylindrical brass borer such as had already been used by Dr. H. Vine and described by one of us (F.H.) for investigating moisture and air conditions in Trinidad cacao soils*. By using the porosity constants derived from measurements made on these special constant-volume samples, it was possible to interpret the periodic moisture data in terms of *volumes* of water, free air-space and solid material comprising the cores of undisturbed soil at each instant of sampling.

(II) Classification of the Soils and Sites Investigated

The soils whose moisture profiles were investigated may be classified according to the provisional scheme already proposed by one of us (E.M.C.)† as follows :—

(I) DRAINAGE FREE. Sands, loams, friable crumby silts and some clays ; high porosity and permeability ; perched water-tables nonexistant ; ground water-tables very deep.‡

(A) *Calcareous parent materials* :—
No representatives studied.

(B) *Non-calcareous parent materials* :—
(1) *Caroni Sand* : Sites Nos. 1, 2, 3.

(II) DRAINAGE PARTIALLY IMPEDED. Loams, marly-silts, marly-clays and sandy-clays ; medium porosity and permeability through compaction and restricted perviousness of parent material, or depressed topography ; comparatively moist soils with wet-season perched water-tables quite deep ; ground water-tables very deep.

(A) *Calcareous parent materials* :—
(2) *Marper Silt* : Sites Nos. 4 and 5 ;
(3) *Princes Town Heavy Clay* : Sites Nos. 6 and 7 ;

(B) *Non-calcareous parent materials* :—
(4) *L'Ebranche Clay-Silt* : Sites Nos. 8 and 9 ;
(5) *Sangre Grande Silty-Clay* : Site No. 10.

(III) DRAINAGE IMPEDED. Mostly stiff clays ; low porosity and permeability either through compaction, restricted perviousness of topsoil, or depressed topography ; no water-tables.

(A) *Calcareous parent materials* :—
(6) *Brasso Clay* : Sites Nos. 11, 12 13 ;

(B) *Non-calcareous parent materials* :—
(7) *Ecclesville Clay* : Site No. 14 ;
(8) *Talparo Clay* : Sites, Nos. 15, 16, 17.

The 17 selected sites represent 8 characteristic soil-types out of the 24 major types so far provisionally differentiated in Trinidad. Two of the soil-types (L'Ebranche Clay-Silt and Sangre Grande Silty-Clay) are derived from river alluvial silts. The rest are hilly-land soils derived *in situ* from various kinds of sedimentary rocks (sandstones, claystones, marls and marly-clays) which comprise nearly the whole of Trinidad. The sites were about equally divided between forest reserves (9 sites) and cacao estates (8 sites). The *forest reserves* represented were :—

		Site
(i) Siparia Reserve	Teak plantations	Nos. 1, 2
(ii) Southern Watershed Reserve		No. 3

* Studies on Aeration of Cacao Soils in Trinidad Part I, by H. Vine, H. A. Thompson and F. Hardy. *Trop. Agriculture*, 1942, XIX, 9, pp. 175-180. Also, Studies on Aeration and Water Supply in Some Cacao Soils of Trinidad, by F. Hardy, *Trop. Agriculture* 1943, XX, 11, pp. 207-220.

† The Provisional Classification of the Soils of Trinidad, by F. Hardy, *Trop. Agriculture*, 1940. XVII, 8, pp. 153-158.

‡ For definition of *water-table*, see Section (VIII).

	Site
(iii) Central Range Reserve (Brasso Venado)	Nos. 4, 12, 14, 17
(iv) Nariva Wind-Belt Reserve (Ecclesville)	Nos. 6, 15

The *cacao estates* represented were :—

(i) Marper (Manzanilla)	Nos. 5, 8, 11, 16
(ii) Adivinanza (New Grant)	Nos. 7, 13
(iii) Marcano's Vale (Biche)	No. 9
(iv) Concord (Sangre Grande)	No. 10

(III) Description of the Sites

(1) *Caroni Sand* (Sites Nos. 1, 2, 3) :—Drainage free.

The three sites representing this agriculturally low-grade soil-type were located in the southern teak plantations managed by the Trinidad Forest Department. The first (No. 1) was in a "good" (satisfactory) area lying 1/3 mile west of the Oropuche Road near Siparia. It was situated near the top of a ridge on a slope of 22° to N.N.W. The trees were 5 years old (1935 Coupe). The second (No. 2) was in a "bad" area, where the trees are stunted and only 15 feet tall. It lay ½ mile east of the Oropuche Road and was also situated near the top of a ridge on a slope of 20° to N. The trees here too were 5 years old. The third (No. 3) was in an old plantation of moderately-good teak near the forest bungalow, distant several miles south of the other sites in the western bend of the Southern Watershed Reserve. It was situated on gently sloping land. The trees here were 13 years old (1927 Coupe).

The soil at each site is a medium-coarse sand, except at Site No. 3, where red sandy-clay underlies the sand.

(2) *Marper Silt* (Sites Nos. 4, 5) :—Drainage partially-impeded.

One of the sites representing this highly-productive calcareous soil-type lay in forest land and the other in cacao. The *forest site* (No. 4) lay near the western boundary of the Central Range Reserve at Brasso Venado on a high ridge of sandy limestone associated with calcareous Brasso Clay. The land slopes slightly (6°) to E. The original forest (Crappo-Guatecare-Carat) has been mostly destroyed ; the chief vegetation now is Wild Canes (*Gynerium saggitatum*), with Balisier (*Heliconia Bihai*), Black Roseau (*Bactris major*), Carat Palm (*Sabal mauritiaeformis*), Bois Flot (*Ochroma Lagopus*) and Sugar Apple (*Anona squamosa*), indicative of local moist conditions. The *cacao site* (No. 5) lay behind the manager's house at Marper Estate, Manzanilla, near the top of a ridge on a slight slope (4°). The cacao trees are big and healthy and were said to bear well.

(3) *Princes Town Heavy Clay* (Sites Nos. 6, 7) :—Drainage partially-impeded.

One of the sites in this productive calcareous soil-type lay in forest and the other in cacao. The *forest site* (No. 6) was located at the S.W. edge of the Nariva Windbelt Reserve near the top of a gentle slope about 1¼ mile in from the main road at Ecclesville. The forest here has been much worked over and thinned by exploitation. The land is eroded and parent marlstone lies near to the surface. The *cacao site* (No. 7) was located at Adivinanza Estate, New Grant, just S. of 14½ m.p. on the Rio Claro main road ; 100 yards E. of the manager's house, on a steep hillside sloping 30° to S. The cacao is said to be good and never to suffer from drought.

(4) *L'Ebranche Clay-Silt* (Sites Nos. 8, 9) :—Drainage partially-impeded.

Both sites in this fertile flat-land alluvial soil-type were occupied by cacao, one at Marper Estate (Manzanilla), the other at Marcano's Vale Estate (Biche), both in Eastern Trinidad. At each site the cacao was said to be very good. The Marper site lies near a stream but the Marcano's Vale site is some distance from the river. The water-table thus probably lies nearer the surface at the first site. Both areas are liable to flood only in exceptionally wet years.

(5) *Sangre Grande Silty-Clay* (Site No. 10) :—Drainage partially-impeded.

The single site in this marginal alluvial soil-type lay in a cacao field near a small river at Concord Estate, 2 miles east of Sangre Grande. The cacao trees looked well but showed only a negligible crop of pods. Yields have rapidly declined in this area during the past 25 years.

(6) *Brasso Clay* (Sites, Nos. 11, 12, 13) :—Drainage impeded.

These three sites, the first and the last in cacao, the second in forest, are widely-separated but all are located in hilly country typical of N.E., Central and S.E. Trinidad. The *forest site* (No. 12) at Brasso Venado was located near the top of the west side of a gentle slope. Here the forest was thin and stunted and evidently much worked over. The vegetation consisted chiefly of Hog Plum (*Spondias mombin*), Black Roseau (*Bactris major*), Carat Palm (*Sabal mauritiaeformis*) and Balisier (*Heliconia Bihai*) but it is not typical of the Crappo-Guatecare-Carat ever-green forest association which covers most of the Central Range, being much more open. The first *cacao site* (Marper, No. 11) was located on a hill-slope but the second (New Grant, No. 13) lay on a broad flat-topped area near the main road and almost at the same level as the road. The cacao trees were very good at the first site but drying up, bare and "stag-headed" at the second.

(7) *Ecclesville Clay* (Site No. 14) :—Drainage impeded.

This site lay in forest and was located only 110 yards away from the Brasso Clay forest site at Brasso Venado (No. 12). It occurred at the top of a small mound. The forest vegetation here is not typical of the Central Range Reserve ; it consists of small stunted trees draped with vines,

lianes and Aroid epiphytes and is densely undergrown ; Carat Palm is scarce. The soil surface appeared to be eroded and the upper layers were very hard and difficult to dig.

(8) *Talparo Clay* (Sites No. 15, 16, 17) :—Drainage impeded.

The three sites representing this red clay soil-type comprise two forest sites (at Ecclesville and Brasso Venado) and one cacao site (at Marper). The second of the *forest sites* (No. 17, Brasso Venado) is located on steeply sloping ground near Site No. 14 and showed unmistakable signs of surface erosion as well as forest degeneration. The trees are thin and stunted and draped with abundant lianes ; the vegetation is distinctly a "dry" type, characterised by an abundance of Myrtaceous shrubs. The other forest site occurs on less sloping ground and is not so obviously eroded. The *cacao site* is not typical of Talparo Clay, being too sandy. It lay on a flatish ridge near the edge of a cacao field. Attempts had been made to establish cacao but they had all failed. The vegetation is now a sward of mixed grasses.

(IV) Laboratory Data for Soils at the Different Sites

Laboratory data * for the soil at each of the sites are presented in Table I. They will be considered in a later section.

(V) Results of Moisture Profile Measurements

In Tables II to VI are set out the essential data for the portrayal of the fluctuating conditions of moisture supply and aeration within the 6-foot soil profile at each of the 17 sites during the advance of the wet season of 1940 and the dry season of 1941. The first column gives the depths of the layers that were periodically sampled for moisture content. The second gives the content of organic matter for each layer. The third gives sand contents (particles of diameter 2.0 to 0.02 mm.). The next two columns present the porosity characteristics.

The *non-capillary pore-space* (Column 4) indicates the magnitude of the largest pores, cracks and interstices out of which water drains freely. These pores contain most of the air needed for root respiration ; their size is over 0.01 mm.

The *capillary pore-space* (Column 5) denotes the magnitude of the smallest pores, which retain water against gravity. These micro-pores store most of the moisture some of which may be abstracted by roots by virtue of their large absorptive forces.

The sites are arranged in Tables II to VI according to degree of natural drainage and soil-type. The values in Columns 6 to 12 represent free air-space volume, being the numerical difference between total pore-space volume (Column 4 *plus* Column 5) and volume of water present at the times of sampling. The positions of the serial values in the column depend of what particular week in the bi-monthly period the site was visited.

* The laboratory data were abstracted from the full profile data provided by Mr. G. Rodrigues, in charge of the Analytical Laboratory of the College Chemistry Department.

NOTE : The volume of water at the time of sampling was obtained by multiplying the gross soil moisture content by the apparent specific gravity. Apparent specific gravity was determined on one occasion only for each pit site and this occasion was that when the soils were in the wettest condition. When the moisture figure (expressed as percentage of water on oven-dry soil) is multiplied by the apparent specific gravity of the soil in its wettest state, the volume occupied by the water in the dry season is too small and the volume of air too large by an amount equal to the shrinkage of the sample. Thus the actual figure for air-space *includes the average volume of the cracks*. Dry season sampling would not account for the very large surface cracks as the sampling tool is too small in diameter to cover a wide enough area.

The *monthly rainfall* figures for each area are included in the tables so as to indicate the progress of the seasons. They refer to the nearest Government rainfall station.

(I) Soils Having Free Drainage (Table II)

(1) *Caroni Sand* : The three representatives of this class (Siparia Teak Plantation) show adequate aeration at all times down to the full depth of the profile, except the third site (where the profile is composite, having a clayey subsoil) which shows signs of saturation in the deep layers toward the end of the wet season. These sandy teak soils have high non-capillary pore-space and are perhaps excessively aerated. Conversely, their capillary water-storage capacity is small so that they are deficient in moisture during a large part of the year.

Soil features : The soil at Sites Nos. 1 and 2 is a brownish-grey sand on top, changing below to fawn sand. It is compact but only slightly clayey. Concretions of red iron oxide occur sporadically to 60 inches, and the sand becomes coarser and bright orange in colour near the base. The soil at Site No. 3 is sandy only to 12 inches, changing to tawny clayey-sand at 24 inches, yellow and grey-mottled below.

Laboratory data : (Table I) show a medium-low organic status with low C/N ratio and highly acid conditions for each profile. The best teak soil (No. 1) has most organic matter and deepest humic penetration. The data give evidence of deep profile truncation by surface erosion at each site, especially No. 2.

Root distribution : Teak roots at the "good" site (No. 1) are uniformly dispersed in the upper 30 inches layer. Some go down to 52 inches into the moist zone. At the "bad" site (No. 2), root penetration is shallower (12 inches). At the old site (No. 3), roots are plentiful to 31 inches penetrating into the clay in search of water, but most are confined to the humic layer, 7 to 15 inches thick.

Cracks : These are generally absent at all three sites.

An important feature imparting "goodness" to a sandy teak soil appears to be its organic matter content which may act as a buffer against too violent fluctuations in soil moisture.

Table I

Generalized Laboratory Data for Soil-Types whose Moisture Profiles were Investigated

	1	2	3	4	5	6	7	8	9	10	
Site	Texture Status			Organic Status					Reaction Status		Notes
	Sand	Silt + Clay	Index of Text (I.T.)	Depth of Humic penetration	Average O.M. Content		C/N Ratio		pH Value		
					Top 6″	Humic Zone	Top 6″	Humic Zone	Top 6″	Parent material	
	Per cent.			Ins.	Per cent.						
					(1) Caroni Sand						
1	78	22	3	15	1.9	1.3	8.5	7.6	5.8	4.5	Good Teak
2	83	17	1	11	1.4	1.2	7.9	6.5	5.2	4.0	Bad Teak
3	62	38	12	7	1.7	1.5	10.1	9.7	5.2	4.7	Fair Teak
					(2) Marper Silt						
4	26	74	25	19	6.0	2.9	9.1	7.8	6.5	7.1	Forest
5	33	67	30	19	1.2	0.9	5.2	4.8	5.5	4.5	Cacao
					(3) Princes Town Heavy Clay						
6	6	94	41	15	5.6	2.8	11.1	9.3	7.1	7.4	Forest
7	21	79	34	21	4.8	2.5	7.8	7.6	6.7	7.3	Cacao
					(4) L'Ebranche Clay-Silt						
8	46	54	21	24	3.3	1.7	9.8	7.2	5.2	4.3	Cacao
9	23	77	31	26	4.6	2.0	9.4	7.0	5.6	4.4	Cacao
					(5) Sangre Grande Silty-Clay						
10	12	88	37	16	1.8	1.3	5.7	5.0	5.3	4.3	Cacao
					(6) Brasso Clay						
11	21	79	31	17	3.7	2.2	7.8	6.9	5.4	7.2	Cacao
12	18	82	29	14	3.7	2.1	9.0	7.0	4.6	6.9	Forest
13	5	95	39	17	4.0	2.2	7.5	6.6	6.4	7.5	Cacao
					(7) Ecclesville Clay						
14	7	93	39	14	4.2	2.5	7.6	6.1	4.5	4.0	Forest
					(8) Talparo (red) Clay						
15	11	89	32	10	4.3	2.9	8.3	7.5	5.7	6.4	Forest
16	21	79	27	20	2.8	1.7	8.4	6.9	4.7	4.2	(Grass)
17	3	97	47	20	4.6	2.7	8.3	6.8	5.8	4.5	Forest

Table II

Moisture Profiles for Free Draining Soils

(Seasonal progress of water infill of pore-spaces)

1	2	3	4	5	6	7	8	9	10	11	12
Lr. Dph	Total O.M.	Sand	Porosity Non-Cap.	Cap.	Pore-Space Saturation Deficits (Free Air Space) Volume percentage						
Ins.	%	%	Vol. %		May Jun.	Jly. Aug.	Sep. Oct.	Nov. Dec.	Jan.	Feb.	Mar. Apr. May
(I) Soils Having Free Drainage											
Caroni Sand											
Site 1 : *Siparia Teak Plantation* : *"Good"* ; 1935 *Coupe*											
2	2.2	79	38	6	38	13	40	17	23	38	27
6	1.8	74	36	6	27	17	33	18	18	35	30
12	1.1	67	30	10	23	17	32	18	20	34	29
24	0.6	69	31	9	24	18	28	14	17	31	26
36	0.3	75	35	5	28	32	18	19	18	25	23
48	0.1	78	34	3	35	36	32	26	32	36	36
60	nil	83	48	0	36	37	29	30	33	37	37
72	nil	91	46	0	33	33	28	29	28	33	35
Site 2 : *Siparia Teak Plantation* : *"Bad"* ; 1935 *Coupe*											
2	1.5	87	48	0	43	32	35	19	31	38	39
6	1.3	79	37	6	36	21	30	13	29	31	29
12	1.0	74	35	9	37	25	29	14	27	31	29
24	0.2	80	37	6	33	25	21	18	24	28	28
36	0.1	81	42	0	31	21	21	16	25	31	42
48	nil	86	44	0	34	28	25	25	28	29	35
60	nil	85	44	0	31	30	26	32	31	32	32
72	nil	86	46	0	—	36	28	29	29	30	35
Site 3 :* *Siparia Teak Plantation* : *S.W.R. "Medium"* 1927 *Coupe*											
2	2.7	81	50	0	23	27	43	19	23	41	36
6	1.2	83	45	0	29	33	35	16	30	35	34
12	0.4	83	44	0	38	34	33	18	29	29	32
24	0.4	70	30	10	20	22	13	18	10	18	16
36	0.4	59	15	25	29	22	10	13	11	17	18
48	0.2	49	9	31	22	24	13	14	11	13	17
60	nil	53	15	27	20	23	20	13	12	7	17
72	nil	61	20	20	—	22	19	11	6	7	17
Rainfall (ins.)			1940 : Wet Season 1.0 6.2		4.9	13.4	2.3	5.4 9.3 4.1	1941 : Dry Season 1.7	0.7	0.5 0.6 4.7

* A composite profile ; sandy to 12 inches, sandy-clay below.

NOTE : Values less than 10 may be regarded as definitely denoting *unsatisfactory* aeration and approximate saturation by water.

(II) Soils Having Partially Impeded Drainage

(A) Calcareous Soil-Types (Table III)

(2) *Marper Silt* : The two examples representing this fertile soil-type, not only have large non-capillary pore-space volume which renders them very permeable to water, but their surfaces are covered with natural crumb soil which readily absorbs the rain. These features doubtless account for their rapid filling up with water during wet periods and their equally rapid emptying during dry weather, features which are clearly revealed by the moisture profile data. Thus the rains of the two wet periods, June-July-August and November-December, only temporarily saturated each soil and each drained more-or-less completely so as to leave the non-capillary pores full of air during the intervening and succeeding dry spells. Irregularities in the behaviour of the cacao soil (No. 5) may be attributed to a higher clay content in the middle zone causing a diminution in non-capillary pore-space. The changes in the moisture profile of the Marper Silt cacao soil (No. 5) are shown in the top row of the diagram which clearly reveals the increasing non-capillary porosity down the profile when the parent rock is approached.

Table III

Moisture Profiles for Partially Impeded Draining Soils

(Seasonal progress of water infill of pore-spaces)

1	2	3	4	5	6	7	8	9	10	11	12
Lr. Dph	Total O.M.	Sand	Porosity Non-Cap.	Cap.	Pore-Space Saturation Deficits (Free Air Space) Volume percentage						
Ins.	%	%	Vol. %		Apr. May	Jun. Jly.	Aug. Sep.	Oct. Nov.	Dec.	Jan.	Feb. Mar. Apr. May
(II) Soils Having Partially-Impeded Drainage (A) Derived from calcareous parent materials											
Marper Silt											
Site 4 : *Central Range Forest Reserve, Brasso Venado*											
2	7.8	24	26	36	38	12	5	16	5		33
6	4.2	25	21	36	33	16	15	25	1		31
12	2.1	19	24	24	25	—	9	18	0		22
24	1.2	30	15	29	19	12	7	12	0		13
36	0.7	0	15	28	23	20	5	16	0		15
48	nil	0	16	26	24	27	10	12	8		20
60	nil	0	17	25	24	32	10	18	4		18
72	nil	0	18	24	26	32	—	—	8		12
			1940 : Wet Season							1941 : Dry Season	
Rainfall (ins)			0.5 4.1 9.310		614.9	5.3	3.412		819.2	3.8 3.2 1.3	0.93.8
Site 5 : *Marper Cacao Estate* : *Manzanilla* (*See* diagram, Row 1).											
2	1.4	53	31	30	21	19	11		17	26 31	37
6	1.1	27	11	42	15	8	10		10	19 22	14
12	0.9	24	7	43	18	10	7		12	11 27	18
24	0.8	29	8	42	12	6	3		15	8 7	4
36	0.6	33	5	45	14	9	6		11	8 0	9
48	0.3	37	15	38	16	13	18		16	11 5	20
60	0.3	43	16	35	18	16	12		8	13 12	21
72	nil	30	11	40	24	19	10		19	15 14	22
			1940 : Wet Season							1941 : Dry Season	
Rainfall (ins.)			2.3 5.4 10.4		10.211	45.7	7.3	14.7	11.9	4.02 42.0 1.4	4.2
Princes Town Heavy Clay											
Site 6 : *Nariva Windbelt Forest Reserve, Ecclesville*											
2	10.7	28	15	49	35	0	0	0	0	13	34
6	3.1	19	7	51	23	0	0	0	0	8	21
12	1.0	4	1	55	24	1	1	2	0	6	18
24	0.7	2	8	49	23	0	0	0	0	8	18
36	0.4	7	4	52	21	11	4	0	5	0	12
48	0.5	4	5	49	20	15	5	6	8	7	19
60	0.3	4	2	49	12	7	3	0	0	8	8
72	0.4	4	3	50	14	7	6	6	6	8	9
			1940 : Wet Season							1941 : Dry Season	
Rainfall (ins).			1.2 5.5		7.3	8.7	16.1	4.4	6.2 9.9	10.2	5.0 1.4 0.9 1.2 5.6
Site 7 : *Adivinanza Cacao Estate, New Grant*											
2	6.0	10	4	55	26	1	9		0	1	17
6	4.3	9	10	53	23	4	15		0	0	19
12	2.5	6	7	56	14	5	7		0	0	10
24	0.9	15	11	46	8	2	19		2	0	17
36	0.6	26	16	36	36	24	20		18	15	23
48	0.3	29	14	32	21	10	16		15	8	15
60	0.2	28	1	39	13	4	7		7	2	9
72	0.2	25	9	37	19	16	19		19	15	18
			1940 : Wet Season							1941 : Dry Season	
Rainfall (ins.)			0.7 5.2		11.0	11.9	17.9	3.2	6.7 15.7	14.0	4.8 1.9 1.2 1.2 6.9

NOTE: Values less than 10 may be regarded as definitely denoting *unsatisfactory* aeration and approximate saturation by water.

Soil features: The soil at each site is a dark-brown to black friable crumbly sandy-loam resembling Rendzina. Below 16 inches, it is a brown-orange loamy sand containing gritty rotten calcareous stones and ferruginous specks.

Laboratory data: (Table I) show similar humic penetration (to 19 inches) at each site but the forest soil is much richer in organic matter. The low C/N ratio of the cacao soil indicates relatively low productivity. This soil is possibly eroded.

Root distribution: Roots are abundant in the humic zone but most occur in the upper 8 inches. Some penetrate below 60 inches. Fibrous roots are mostly confined to the surface 1½ inch layer under a thick leaf litter.

Cracks: These are rare and none goes deeper than 24 inches.

Marper Silt is one of the most productive soil-types in Trinidad; both its physical and its chemical attributes are highly satisfactory.

(3) *Princes Town Heavy Clay*: The two examples of this fertile Rendzina soil possess lower non-capillary pore-space than the Marper Silt examples and their internal drainage is more impeded. The forest soil, however, is covered with a powdery humic layer containing a considerable amount of sand whereas the cacao soil is devoid of crumb and presents a hard glazed surface which, together with the steeply-sloping topography, probably account for the marked differences which its moisture profile exhibits when compared with the forest soil. During the greater part of the wet season, the forest soil-profile seems to be nearly saturated throughout its whole depth, though it apparently dries out rapidly in the dry season. On the other hand, the cacao soil-profile is saturated only intermittently and water does not penetrate so deeply, not necessarily because of a lesser degree of porosity, but because much water is shed, the surface layer having only small infiltrability.

Soil features: The *forest* soil is a black to sepia clay, powdery and sandy on top to 3 inches, cloddy below to 15 inches, then changing sharply to calcareous golden-brown clay, merging into grey marly-clay or rotten marlstone at 24 inches. The profile is calcareous below 10 inches suggesting marked truncation by erosion.

The *cacao* soil is black clay to 12 inches, sepia to 21 inches and pale-brown and calcareous to 36 inches where it merges into crumbly marlstone. The surface is not powdery nor crumby but hard, compact and cloddy, as if damaged by erosion or trampling.

Laboratory data: (Table I) show deeper humic penetration at the cacao site than at the forest site (21 inches against 15 inches); the first appears not to be so deeply eroded as the second. The C/N ratio ot the cacao soil is low denoting a soil of relatively low productivity. The reaction profile is alkaline in the forest soil but slightly acid to 12 inches in the cacao soil.

Root distribution: Tree roots at the *forest* site penetrate to 60 inches well into the parent marlstone, but most occur within the humic zone, 15 inches thick. There is a distinct fibrous root-mat, one inch thick on the surface. At the *cacao* site, thick roots are abundant in the upper 4 feet, and some go as deep as 6 feet, though most occur in the humic layer. The surface is covered with a mat of fibrous roots. The only other soil-type in which such deep roots occur is Chocolate Soil.

Cracks: These are mainly small and go down to 15 or 24 inches.

Princes Town Heavy Clay, generally regarded as a fertile soil-type, shows differing degrees of productivity depending mainly on the amount of erosion which the profile may have suffered. The natural crumb layer in the normal phase is rich in plant nutrients and remarkably stable; its granular surface renders the soil highly infiltrable to water and thus profoundly affects its internal water relations. The occasional presence of abnormal amounts of sand in the surface layer of the profile (as at the forest site) doubtless enhances water entry.

(B) Non-Calcareous Soil-Types (Table IV)

(4) *L'Ebranche Clay-Silt*: The two examples of this alluvial cacao soil owe their drainage impedence to depressed topography and to some extent to low non-capillary porosity. The first site (No. 8, Marper) is nearer a river than the second (No. 9, Biche), but each site is liable to flood though only in unusually wet seasons. In spite of a fairly large non-capillary porosity in the soil at Marper, the profile appears to be saturated for the greater part of the year. On the other hand, the soil at Biche is well aerated the whole year round in its surface 2-inch layer, and to the 12-inch depth for the greater part of the dry season, conditions well suited to the growth of the cacao tree.

The moisture profile fluctuations for the L'Ebranche Clay-Silt cacao soil at Marcano's Vale, Biche, are shown in the second row of the diagram which clearly indicates temporary saturation below the 2-inches depth during the wet season, though the soil below 24 inches remains well aerated.

Soil features: This soil is a yellow-brown heavy silt containing variable amounts of sand, becoming paler and orange-speckled to 17 inches below which it is grey, mottled orange-brown. The lower layers thus resemble gley, whose features are due to water-logging. The surface is covered with a well-marked natural crumb layer, 2 inches thick.

Laboratory data (Table I) show that the Marper alluvial soil (No. 8) is more sandy than the Biche soil (No. 9). Humic penetration is about the same in each but the latter is richer in organic matter. Both show a high C/N ratio (9.6) indicating productive cacao soil. Both are highly acid (pH 5.4), being derived from well weathered non-calcareous parent materials.

Root distribution is superficial, as would be expected. Few roots descend below 36 inches; most occur in the top 9 or 12 inches. Fibrous roots are abundant in the crumb layer but most are concentrated in a root-mat ½ inch thick, under a thick leaf litter. No living roots can be seen below 5 feet but old root traces occur at 8 feet.

Cracks mostly stop at 15 inches; they are numerous though fine.

Table IV

Moisture Profiles for Partially Impeded-Draining Soils

(Seasonal progress of water infill of pore-spaces)

1	2	3	4	5	6	7	8	9	10	11	12
Lr. Dph	Total O.M.	Sand	Porosity Non-Cap.	Cap.	Pore-Space Saturation Deficits (Free Air Space) (Volume percentage)						
ins.	%	%	Vol. %		May	Jun. Jly.	Aug.Sep.	Oct.Nov.	Dec. Jan.	Feb.Mar.	Apr. May
(II) Soils Having Partially Impeded-Drainage											
(B) Derived from non-calcareous parent materials											
Alluvial Soils											
L'Ebranche Clay-Silt											
Site 8 : *Marper Cacao Estate* : *Manzanilla*											
2	5.2	50	14	37	2	0	0	0	0	14	0
6	2.4	48	15	36	13	0	0	0	7	16	10
12	1.8	42	9	36	7	0	2	0	1	9	3
24	1.0	45	15	31	10	0	3	4	1	0	13
36	0.5	58	19	21	0	0	0	0	0	8	8
48	0.6	54	19	23	0	0	4	4	1	7	0
60	1.1	42	1	38	0	0	0	0	0	0	0
72	1.7	32	0	37	0	0	0	0	0	0	0
			1940 : Wet Season						1941 : Dry Season		
Rainfall (ins.)			5.4	10.4	10.2	11.4	5.7	7.3	14.7	11.9	4.0 2.4 2.0 1.4 4.2
Site 9 : *Marcano's Vale Cacao Estate* : *Biche* (*See* diagram Row 2).											
2	5.5	25	25	38	33	15	13	24	20	28	33
6	4.2	24	14	42	19	6	5	1	9	19	12
12	1.8	22	6	44	13	2	0	0	4	13	13
24	1.1	24	6	42	9	1	2	1	8	13	8
36	0.6	20	5	42	12	8	7	6	8	7	11
48	0.6	22	9	40	13	8	13	7	11	1	11
60	0.7	28	6	39	0	6	7	6	7	2	7
72	0.5	25	4	41	6	6	10	2	7	3	6
			1940 : Wet Season						1941 : Dry Season		
Rainfall (ins.)			4.6	10.5	9.5	11.7	4.5	4.8	17.2	11.5	8.4 2.1 1.5 1.0 4.9
Sangre Grande Silty-Clay											
Site 10 : *Concord Cacao Estate* : *Sangre Grande*											
2	2.2	23	24	36	24	0	0	18	1	28	33
6	1.6	21	12	42	14	0	0	21	0	24	19
12	1.2	18	10	43	8	0	0	0	4	18	14
24	0.6	15	0	48	0	1	0	18	0	12	5
36	nil	16	0	52	2	5	3	12	1	9	9
48	nil	10	0	56	4	4	4	6	3	5	6
60	nil	5	0	51	4	4	4	6	3	7	8
72	nil	6	3	52	10	9	9	14	4	14	14
			1940 : Wet Season						1941 : Dry Season		
Rainfall (ins.)			4.9	12.6	8.1	13.0	5.8	9.3	10.3	12.8	3.1 1.1 1.2 1.1 5.6

NOTE : Values less than 10 may be regarded as definitely denoting *unsatisfactory* aeration and approximate saturation by water.

(5) *Sangre Grande Silty-Clay*: The single example of this widespread marginal alluvial soil resembles in its general water and air relations the Biche alluvial soil described above. It appears to be almost completely saturated with water during the wet season but it dries out to the 6 or 12 inches depth during dry weather. Non-capillary porosity is *zero* below 12 inches, and this, coupled with the depressed topography (the site being near a river) account for its impeded drainage.

Soil features: The soil is a pale brownish-fawn crumbly clay to 9 inches, brown-mottled to 15 inches then pale grey below, mottled orange and spotted with rusty ferruginous concretions and black manganese oxide deposits characteristic of the *gley* layer.

Laboratory data (Table I) show a low organic status with only medium humic penetration (to 16 inches) and very low C/N ratio (5.7), denoting a cacao soil of low productivity. The reaction is highly acid throughout. The profile shows signs of surface erosion with loss of natural crumb layer.

Root distribution is most abundant in the upper 6-inch layer and few roots penetrate below 60 inches. Old root traces are abundant at 60 to 72 inches. There is a well-marked ¼-inch root-mat but no conspicuous crumb layer.

Cracks penetrate to 36 inches during dry weather but they close up with the early rains.

NOTE: The *Sangre Grande Silty-Clay* soil-type has previously been investigated at Las Hermanas Cacao Estate *. As at Concord, the soil there is apparently fully saturated with water below the 6-inch depth for most of the year, and adequate amounts of moisture and air are available together only during the early part of the wet season and the later part of the dry season, that is, for about one quarter of the year.

(III) Soils Having Impeded Drainage

(A) Calcareous Soil-Types (Table V)

(6) *Brasso Clay*: The soil profile at the Brasso Clay forest site (No. 12) apparently took the longest time to fill up with water as the wet season progressed, even though its non-capillary pore-space is not the smallest. It started filling toward the end of May and was almost replete by the end of August. Later its water content dried out above without ever reaching saturation point at the full 72 inches depth. In the dry season, it probably always dries out deeply and is therefore adequately aerated for at least five months of the year.

The two cacao soil profiles (Sites Nos. 11 and 13) differ somewhat in the amount of non-capillary pore-space, the New Grant example (No. 13) being entirely devoid of macro-pores below the 6-inch depth, its parent clay being very thick. This soil is evidently the most nearly saturated of the three, the layers below 36 inches never being adequately aerated and the superficial layers alone being properly aerated for more than 4 months of the year. The Marper soil (No. 11) is slightly the better aerated of the two cacao soils and behaves similarly to the forest soil.

The changes in the moisture profile at the New Grant cacao site (No. 13) are shown in the third row of the diagram which indicates its high degree of saturation by water in the wet season.

The similarities and differences between the three Brasso Clay sites may largely be explained by the peculiar surface features of the soils and by their particular topography. The forest soil and the Marper cacao soil have lost their natural crumb layers so that the soil surface is compact and exhibits low infiltrability; they crack deeply during drought and water penetrates mainly *via* the fissures when the rains begin. The soil column thus fills up with water rather slowly but never attains saturation. On the other hand, the New Grant site (No. 13) is flat and the run-off is not so rapid, so that water lies longest on the land. Moreover, the soil surface, though not markedly crumby, has relatively high non-capillary porosity favouring rapid penetration; water thus tends to remain in the surface layer.

Soil features: Brasso Clay soil is a yellow-brown, compact, stiff clay showing only sparse humic staining, changing gradually through ochre-yellow clay mottled orange to rotten, crumbly, olive-green silt-stone at 20 to 36 inches, containing ferruginous and calcareous concretions. The New Grant soil contains gypsum veins below 48 inches. The surface layer at each site is not typically crumby but shows coarse cloddy structure.

Laboratory data show a similar organic status at each of the three sites. Organic penetration is about 16 inches. The C/N ratios of the two cacao soils are rather low (7.7) and denote soils of medium productivity. The top 6 inches of soil is highly acid at the forest site and at the Marper cacao site but only slightly acid at the New Grant cacao site. In each case the reaction becomes rapidly less acid downwards and is alkaline where free calcium carbonate appears.

Root distribution is deep in the *forest soil* (60 inches) though most roots occur in the top 24 inches. The fibrous roots tend to concentrate in the upper 3 inches layer. There is no distinct root mat, and leaf litter is sparse.

In the *cacao soils*, roots are prevalent in the top 36 inches zone, and some penetrate below 72 inches but most occupy the humic layer. There is a ½ inch root-mat at the Marper site but at the New Grant site fibrous roots occur more widely dispersed in the upper 2 inches of humic soil.

Cracks go down to about 38 inches.

Brasso Clay is a distinctive semi-Rendzina cacao soil-type wide-spread in East Trinidad where it has a reputation for high productivity for cacao. It is very variable, however, mainly because of its differing degree of non-capillary porosity, its undulating topography, the varying depth of the calcareous parent rock below the surface, and the changeable features of its uppermost layer which normally is coarsely-crumby to

* *See*: Studies on Aeration of Cacao Soils in Trinidad; H. Vine, H. A. Thompson and F. Hardy; *Trop. Agriculture*, Part II; XIX, pp.215-223; Part III; XX, pp.13-23; Part V; XX, pp.89-104.

Table V

Moisture Profiles for Impeded-Draining Soils

(Seasonal progress of water infill of pore-spaces)

1	2	3	4	5	6	7	8	9	10	11	12
Lr. Dph	Total O.M.	Sand	Porosity Non-Cap.	Cap.	Pore-Space Saturation Deficits (Free Air Space) (Volume percentage)						
ins.	%	%	Vol. %		Apr.May	Jun. Jly.	Aug.Sep.	Oct. Nov.	Dec. Jan.	Feb.Mar.	Apr. May
					(III) Soil Having Impeded-Drainage						
					(A) Derived from calcareous parent materials						
Brasso Clay											
Site 11 : *Marper Cacao Estate : Manzanilla*											
2	4·7	35	6	47	1	0	0	3	5	3	20
6	3·3	32	4	48	9	5	0	0	6	9	14
12	2.0	28	2	48	0	2	0	1	0	11	6
24	0.7	24	2	45	3	0	0	2	0	14	7
36	0.6	28	3	46	14	17	7	10	8	14	17
48	0.6	12	3	44	20	22	5	11	10	17	17
60	0.7	19	0	44	21	18	8	7	7	15	13
72	0.4	16	0	45	20	18	20	13	11	18	16
					1940 : Wet Season				1941 : Dry Season		
	Rainfall (ins.)		2.3 5.4 10.4		10.2 11.4 5.7	7.3	14.7	11.9	4.0 2.4	2.0 1.4	4.2
Site 12 : *Central Range Forest Reserve ; Brasso Venado*											
2	5·3	26	20	37	38	16	2	0	7	23	—
6	2.1	15	6	44	29	19	0	2	4	16	—
12	1.0	21	1	45	24	11	3	0	1	4	—
24	0.7	16	3	40	20	8	2	0	1	2	—
36	0.6	0	2	42	21	21	7	13	7	13	—
48	nil	0	1	41	18	19	4	10	12	18	—
60	nil	0	2	38	17	17	11	15	13	13	—
72	nil	0	2	40	18	19	14	19	14	22	—
					1940 : Wet Season				1941 : Dry Season		
	Rainfall (ins.)		0.5 4.1 9.3		10.6 14.9 5.3	3.4	12.8	10.2	3.8 3.2	1.3 0.9	3.8
Site 13 : *Adivinanza Cacao Estate, New Grant* (*See* diagram, Row 3)											
2	5.4	10	9	50	32	0	10	1	12	24	25
6	2.9	13	5	50	26	2	7	2	2	21	23
12	1.3	13	0	51	15	0	0	0	0	14	9
24	0.7	3	0	53	24	0	4	0	0	9	8
36	0.3	3	0	49	16	0	0	0	0	0	9
48	nil	2	0	48	10	0	0	0	0	0	9
60	nil	4	0	47	0	2	0	0	0	0	9
72	nil	4	0	48	3	3	1	0	0	0	5
					1940 : Wet Season				1941 : Dry Season		
			0.7 5.2 11.0		11.9 17.9 5.2	6.7	15.7	14.3	4.8 1.9	1.2 1.2	6.6

NOTE : Values less than 10 may be regarded as definitely denoting *unsatisfactory* aeration and approximate saturation by water.

Table VI

Moisture Profiles for Impeded-Draining Soils

(Seasonal progress of water infill or pore-spaces)

1	2	3	4	5	6	7	8	9		10	11	12
Lr. Dph	Total O.M.	Sand	Porosity Non-Cap.	Cap.	Pore Space Saturation Deficits (Free Air Space) (Volume percentage)							
ins.	%	%	Vol. %		Apr.May	Jun. Jly.	Aug.Sep.	Oct.Nov.	Dec.	Jan.	Feb.Mar.	Apr.May
(III) *Continued*—Soils Having Impeded-Drainage (B) Derived from Non-calcareous parent materials												
Ecclesville Clay												
Site 14: *Central Range Forest Reserve: Brasso Venado*												
2	5.7	6	10	47	35	33	6	21	14		21	—
6	2.8	5	5	51	33	22	0	24	8		27	—
12	1.3	3	4	51	32	12	9	24	9		26	—
24	0.6	9	3	47	28	10	2	18	3		18	—
36	0.6	0	0	47	26	21	11	19	11		16	—
48	nil	0	0	44	20	19	18	16	20		18	—
60	nil	0	0	42	—	—	15	9	19		14	—
72	nil	0	0	41	—	—	12	4	14		16	—
					1940: Wet Season						1941: Dry Season	
Rainfall (ins.)					0.5	4.1 9.3	10.6	14.9	5.3 3.4	12.8 10.2	3.8 3.2 1.3 0.9 3.8	
Talparo Clay												
Site 15: *Nariva Windbelt Forest Reserve: Ecclesville*												
2	6.6	32	12	44	23	11	0	0	0		15	27
6	3.2	23	4	49	19	5	0	0	0		14	23
12	0.8	10	4	47	20	4	0	0	0		14	18
24	0.5	7	3	47	16	6	4	2	2		11	19
36	0.2	12	8	42	8	9	0	7	7		7	16
48	nil	10	2	45	2	6	2	3	2		3	9
60	nil	10	3	39	8	14	12	15	15		16	15
72	nil	8	6	44	9	10	6	11	10		13	10
					1940: Wet Season						1941: Dry Season	
Rainfall (ins.)					1.2	5.4 7.3	8.7	16.1	4.4 6.2	9.9 10.2	5.0 1.4 0.9 1.2 5.6	
Site 16: *Marper Cacao Estate: Manzanilla*												
2	3.0	39	36	24	35		18	29	42		39	43
6	2.7	40	28	27	28		17	22	23		27	30
12	1.8	33	22	29	14		10	16	21		22	22
24	0.9	24	11	39	12		15	9	15		16	17
36	0.4	14	0	44	8		6	2	2		6	2
48	0.3	20	2	39	4		0	0	0		0	4
60	nil	15	0	40	5		5	2	0		2	4
72	nil	19	0	40	4		0	0	—		—	6
					1940: Wet Season						1941: Dry Season	
Rainfall (ins.)					2.3	5.4 1.04	10.2	11.4	5.7 7.3	14.7 11.9	4.0 2.4 2.0 1.4 4.2	
Site 17: *Central Range Forest Reserve: Brasso Venado*												
2	5.8	4	10	52	42		—	4	24		14	33
6	3.4	5	5	54	37		—	12	21		14	29
12	2.4	3	2	57	34		—	16	23		16	25
24	1.5	3	4	51	28		—	13	23		17	28
36	0.6	0	1	47	—		—	20	16		20	22
48	nil	0	0	44	—		—	17	14		17	23
60	nil	0	0	42	—		—	—	12		15	7
72	nil	0	0	40	—		—	—	7		—	—
					1940: Wet Season						1941: Dry Season	
Rainfall (ins.)					0.5	4.1 9.3	10.6	14.9	5.3 3.4	12.8 10.2	3.8 3.2 1.3 0.9 3.8	

NOTE: Values less than 10 may be regarded as definitely denoting *unsatisfactory* aeration and approximate saturation by water.

fine cloddy and highly humic, showing ready infiltrability to rain-water. Drainage impedence is therefore also variable depending primarily on the occurrence of impervious plastic clay that comprises the non-humic subsoil. The forest profile was remarkable in being practically completely dry below the 30 inches depth throughout the year.

(B) Non-Calcareous Soil-Types (Table VI)

(7) *Ecclesville Clay*: The single example of this soil-type (a forest soil), though devoid of non-capillary pore-space in its profile layers below 2 feet, nevertheless maintains adequate aeration for the greater part of the year, or in other words maintains a relatively dry condition in spite of high rainfall. The reason for this appears to be the extremely low infiltrability of the surface soil which entirely lacks a crumb layer and is compact and glazed so that it sheds water easily. The site occurs on sloping ground which expedites run-off. The vegetation is a "dry" type of forest which accords with the peculiar features of the soil and the site.

Soil features: Ecclesville Clay is a dark fawn, hard, cloddy clay to 2 inches, paler and yellower in colour below with orange and brown speckling. It changes at 12 inches to rotten nodular olive-green clay-stone, containing ferruginous concretions, manganese oxide stains and veins of gypsum.

Laboratory data show a medium organic status with low C/N ratio. The profile is probably deeply truncated by erosion, which would account for this feature.

Root distribution is confined mostly to the surface 1 inch layer; few roots go deeper than 9 inches and very few penetrate below 30 inches; the deepest roots occur pressed between fissure planes. There is a distinct root-mat and a fair leaf litter.

Cracks go to 25 inches well into the parent claystone.

(8) *Talparo Clay*: One of the two *forest* sites representing this red clay soil-type, namely No. 17 (Brasso Venado), closely resembles the Ecclesville Clay forest site last considered in that it is occupied by a "dry" kind of forest and the soil profile shows an unusually high degree of unsaturation by water throughout the whole year. The soil surface at this red clay site is particularly infiltrable, being quite devoid of crumb. The changes in the moisture profile at the "dry" Brasso Venado forest site (No. 17) are shown in the bottom row of the diagram.

The soil at the other forest site (No. 15, Ecclesville) behaves differently. Here the land is much less sloping and the soil surface is quite sandy to 6 inches and not so compact, so that water does not run away so readily. It is also relatively permeable below. The moisture profile data show that this soil is nearly saturated during the rainy season (June to December) though it rapidly dries out from above downwards as the dry season progresses. When dry, the soil is deeply cracked and hard to dig.

The *cacao* site (No. 16, Marper) differs markedly from the two forest sites on Talparo Clay in its much larger non-capillary porosity in the upper part of the soil profile, especially the top 12 inches. This is because the soil is sandy and not at all typical of Talparo Clay; it contains 36 per cent. of sand in the top 12 inches, and 18 per cent. below the 36 inches depth, whereas typical Talparo Clay seldom contains more than 10 per cent. of sand in any part of the profile. This cacao soil is well aerated in the upper part of the profile throughout the year, though apparently continuously saturated below the 24 inches depth where the soil is least porous.

Soil features: The soil at the two *forest* sites is a yellow-brown tough cloddy clay, changing between 6 and 12 inches to a salmon-red-mottled grey clay to 24 inches, below which the red mottling disappears, the subsoil being an orange-ochre compact clay mottled grey. Signs of bedding appear at 26 inches. The parent rock is a green-grey fine clay-stone, highly gypseous, non-calcareous, hard and soapy. Conspicuous bands of red ferruginous concretions occur below 28 inches.

The soil at the *cacao* site is red-mottled only below 18 inches, the layer above being fawn and grey and quite sandy. Transition to parent claystone occurs at 44 inches.

Laboratory data (Table I) show deep humic penetration at the Brasso Venado forest site (No. 17) and at the Marper cacao site (No. 16), though the organic matter content of the cacao soil is relatively low and the C/N ratio medium, indicative of only medium productivity. The Ecclesville red clay forest site shows shallow organic penetration but fairly high organic matter content. The reaction is highly acid throughout each profile.

Root distribution: Tree roots are thinly dispersed at the *forest* sites within the red-mottled zone but fairly abundant in the overlying humic soil. A sparse root-mat, 1 inch thick, covers the surface under a thin leaf litter. There is no natural crumb layer at the Brasso Venado forest site. At the Ecclesville forest site the surface 6 inches layer is cloddy and somewhat sandy; fibrous roots ramify throughout this layer. At the *cacao* site, roots are mostly confined to the top 6 inches layer; there is no root-mat except that of the grass sod.

Cracks are mostly shallow at all three sites; they are about 9 inches deep though some go to 36 inches at the Brasso Venado forest site which is the least sandy and the driest of the three.

(VI) Rainfall during the Investigational Period

The monthly rainfalls during the period of the investigation (April, 1940 to May, 1941) are brought together in Table VII where they are arranged in decreasing order for districts in which the sites were located. The monthly means for all but the relatively dry Siparia district are also stated.

The total annual rainfall at six of the sites during 1940-1941 was 85 inches which is about 5 inches below the 18 years' average because of the abnormally dry dry season of 1941. The mean *monthly* rainfall for the five dry season months was 2.9 inches but only 1.5 inches for the three middle months. The rainfall during the wet season was quite normal (70.5 inches in 7 wet months) though the mean monthly rainfalls varied somewhat from normal, there being a particularly

Table VII

Monthly Rainfall Data

	Apr.	May	Jun.	Jly.	Aug.	Sep.	Oct.	Nov.	Dec.	Total Wet	Jan.	Feb.	Mar.	Apr.	May	Total Dry	Total 1941
	1940		Wet Season								1941 Dry Season						
New Grant	0.7	5.2	11.0	11.9	17.9	3.2	6.7	15.7	14.3	80.7	4.8	1.9	1.2	1.2	6.6	15.7	96.4
Biche ...	1.3	4.6	10.5	9.5	11.7	4.5	4.8	17.2	11.5	69.7	8.4	2.1	1.5	1.0	4.9	17.9	87.6
Manzanilla	2.3	5.4	10.4	10.2	11.4	5.7	7.3	14.7	11.9	71.6	4.0	2.4	2.0	1.4	4.2	14.0	85.6
Sangre Grande ...	1.7	4.9	12.6	8.1	13.0	5.8	9.3	10.3	12.8	71.9	3.1	1.1	1.2	1.1	5.6	12.1	84.0
Brasso Venado	0.5	4.1	9.3	10.6	14.9	5.3	3.4	12.8	10.2	66.5	3.8	3.2	1.3	0.9	3.8	13.0	79.5
Ecclesville	1.2	5.5	7.3	8.7	16.1	4.4	6.2	9.9	10.2	62.8	5.0	1.4	0.9	1.2	5.6	14.1	76.9
Means ...	1.3	5.0	10.2	9.8	14.2	4.8	6.3	13.4	11.8	70.5	4.9	2.0	1.4	1.1	5.1	14.5	85.0
Siparia ...	0.3	1.0	6.2	4.9	13.4	2.3	5.4	9.3	4.1	45.6	1.7	0.7	0.5	0.6	4.7	8.2	53.8
For Comparison	Mean monthly and annual rainfall of the above sites for 18 years.																
First 6 Sites	3.3	5.7	11.3	11.5	10.0	8.7	8.1	10.4	10.5	70.5	5.1	3.1	2.4	3.3	5.7	19.6	90.1
Siparia ...	2.1	3.9	4.2	8.9	9.4	7.2	7.6	8.6	7.2	53.1	3.8	2.4	1.7	2.1	3.9	13.4	66.5

dry "petite careme" (Indian summer) in September (4.8 inches) which divided the wet season into nearly equally-rainy halves each having average monthly rainfall of about 11 inches. The total rainfall at Siparia was only 54 inches which was much less than average (66.5 inches), again mainly because of an abnormally dry season and a marked petite careme.

(VII) Discussion of Results

The following main deductions are drawn from the tabulated moisture profile data contained in the tables. The seventeen different soils fall into six distinct categories, as follows.

(1) The *Siparia sites* (Nos. 1, 2, 3 :—Table II) are exceptional in that the soil is very loose and sandy and its capillary storage-porosity is so small that plants probably suffer water-shortage practically the whole year round, except when rain is actually falling. On the other hand the soil is fully aerated at all times, except the composite profile (No. 3) whose clayey subsoil was nearly saturated by water on several occasions at the end of the wet season.

Similar sandy soils (Caroni Sand, Valencia Sand, Piarco Sand) occur in various parts of Trinidad but they are frequently underlaid by clayey substrata, so that in many places their internal drainage is more-or-less impeded. They are classed as Grade IV for cacao production and should mostly be relegated to forest.

(2) The *L'Ebranche Clay-Silt sites* (Nos. 8, 9) and the *Sangre Grande Silty-Clay site* (No. 10 :—Table IV) are the only *alluvial soils* in the series. They are exceptional in that their almost constant saturation at all depths except the surface 2 or 6 inches is mainly due to depressed topography although all but the first have in addition small non-capillary porosity below the 6-inch depth.

Similar low-lying alluvial soils are widespread over the river vegas of Trinidad, especially in the Northern Plain. Their suitability to cacao-growing seems to depend chiefly on the features of the shallow upper layer which in satisfactory cases is markedly crumby and well protected by a layer of litter under which a fibrous root system (bichet) abundantly develops. Similar conditions and soil features characterise the "home of cacao" which is believed to be the riverain alluvial strips bordering the Amazon River.

The Trinidad alluvial soils are mostly classed as Grade II and III for cacao and have variable productivity. Many sites have apparently suffered considerable surface erosion through floods.

(3) The *Marper Silt sites* (Nos. 4, 5 :—Table III) represent porous hilly-land soils overlying calcareous siltstone. They are freely drained except where layers of clay are interposed at different depths in the profile.

Soils of this type are not widespread in Trinidad and occur in few localities only, mainly near Basseterre north of Moruga, and in the Manzanilla District of East Trinidad, with sporadic occurrences also in the Central Range. The surface features are usually favourable for rapid water uptake but the soils may dry out badly between rainy periods. Marper silt is classed as Grade I and II for cacao.

The remaining nine sites are loamy-silts and clays having high capillary porosity but relatively low non-capillary porosity. They differ markedly among themselves in their water relations mainly because of the varying degree of penetration by rainwater during the wet season. This in turn depends on three important site features, namely:—

(i) infiltrability for water of the soil surface,
(ii) degree of land slope,
(iii) relative permeability of the different profile layers, decided chiefly by non-capillary soil porosity.

The clay sites may be classified on this basis as follows :—

(4) The *Talparo Clay cacao site* (No. 16 :— Table VI) ; the *Brasso Clay cacao site* (No. 13 :— Table V) ; the *Talparo Clay forest site* (No. 15 :— Table VI) and the *Princes Town Heavy Clay forest site* (No. 6 : Table III) which have highly infilterable soil surfaces due to an open porous structure decided mainly, however, by an abnormally-large sand content and not apparently by the presence of a stable crumb layer. They each occupy flattish ridges so that water run-off is not very pronounced. The deeper profile-layers (below 24 inches) are decreasingly permeable because of increasing clayiness which impedes the drainage. For these reasons, the profiles started to fill with water *from the bottom upwards* when percolating rains really set up in June. By the end of July they were replete nearly up to the surface level in every case but the first (the sandiest), and stayed so, more or less constantly, until the end of January. Thus three of the profiles were nearly saturated with water for six months of the year and only their upper parts dried out during the succeeding dry period.

Soils of this peculiar kind (highly absorptive at the surface but variably impermeable below) are probably not very common in Trinidad and their exact distribution is not known. The cacao sites examined are not satisfactory however, nor representative of the two soil-types to which they belong.

(5) The *Princes Town Heavy Clay cacao site* (No. 7 :—Table III), the *Brasso Clay cacao site* (No. 11 :—Table V) and the *Brasso Clay forest site* (No. 12 :—Table V) exhibit soil surfaces that allow little infiltration so that water penetration is almost entirely restricted to fissures and cracks with which these calcareous clays are well provided. The surface of the ground between the cracks is compact, hard and glazed, and seems to have lost most of its natural crumb layer. Moreover, the sites occur on steeply-sloping ground which favours rapid run-off during the rainiest periods. For these reasons, the profiles started slowly to fill up with water from the bottom of the larger cracks at average depth of about 36 inches during May and June. After the end of June and up to the end of January, the upper parts of the profiles above the 24-inch level were frequently nearly or quite saturated with water, but lower down the degree of saturation was never very high within the parent marl which throughout the whole period always contained between 10 and 20 per cent. or more free air-space volume below the 5-foot depth. Thus *a belt of high moisture content* occurred within the soil profiles between the surface and the 5-foot depth below which the porous parent marlstone was always dry.

Soils of this kind are probably fairly common over marlstone and marly-clays in the south and east of Trinidad wherever these rocks outcrop. Provided the soil is covered with a crumb layer adequately protected by litter, their productivity for cacao is generally fairly high (Grade II) but the soils are prone to erosion when they occupy sloping ground (as in the cases described above), so that their productivity may rapidly decline unless measures are taken to prevent surface wash.

(6) The *Ecclesville Clay (forest) site* (No. 14) and the *Talparo Clay (forest) site* (Brasso Venado ; No. 17 ; Table VI), like the last, present soil surfaces that allow little infiltration, being compact, hard and glazed and quite devoid of natural crumb. They are cracked in the dry season down to 2 or 3 feet but the cracks rapidly close during the rains. The sites lie on steep slopes so that run-off is pronounced in rainy weather. For these reasons, the profiles fill up only tardily with water ; indeed they are almost completely dry during the greater part of the year as the data in Table VI and the diagram (bottom row) clearly show. This extraordinary condition is unique among the seventeen profiles studied and was unsuspected before these investigations were planned. It has long been known, however, that certain hilly areas of clay soil occurring in various parts of Trinidad support a dry type of forest, even though the incident rainfall is relatively high. Officers of the Forestry Department have usually referred to the soil associated with dry forest of this kind as "hard red clay" (probably because it mainly belongs to the Talparo Clay soil-type), and regard it as "physiologically dry". Our observation that the soil owes its persistent dryness to low infiltrability of surface, high slope and the rapid sealing of cracks when the ground is wetted is therefore important and significant.

Possibly the dry forest is a degenerate post-climax or "deflected" climax type, the factor that has mainly been responsible for its development presumably being soil erosion aided undoubtedly by indiscriminate felling or exploitation, repeated fire damage and finally wind damage. The complete removal of the all-important surface crumb layer with its protective litter, through exposure and erosion on sloping ground comprising impervious clay soil, may apparently result in a condition of physiological drought. Presumably, any such area lying within the high-rainfall forest belt of Trinidad is liable to this change unless the agencies responsible for it are eliminated. Thus, the incidence of physiological drought was revealed by the moisture profile data for the western end of the Central Range Forest Reserve at Brasso Venado, and it is also believed to occur at the eastern end of the Southern Watershed Forest Reserve lying north of Moruga.

(VIII) Evidence of Water-Tables

If the term water-table is defined as the upper limit of that part of the soil or underlying material which is wholly saturated with water*, then the moisture profile data reveal the occurrence of water-tables at most of the sites investigated, but it is very doubtful if any of them is a *true ground-water-table* since in no case was free water ever found within the 6-foot profile, even at the flat

* "*Soils and Men*" 1938 ; U.S.D.A. Year Book, p.1179.

alluvial sites. Certain of the sites, however, exhibited a tendency to develop *perched water-tables* but the hydrostatic pressure was insufficient to overcome the capillary forces in the saturated soil and so no free water exuded into the pits from their walls. These perched water-tables are of seasonal nature; they are liable to occur at any depth from the surface down to 10 feet during the wet season, though usually non-existent during the dry season. The zone of water-saturation starting at a perched water-table level may have variable thickness, not only at different sites, but also at different times of the year. Furthermore, the zone of saturation may be separated from a deep-seated true ground-water-table by a zone of perfectly dry soil material.

Among the sites examined, the three alluvial cacao sites at Marper, Biche and Sangre Grande (*Category* 2: Table IV) showed a tendency to develop high perched water-tables rising almost to the land surface during rainy weather with a zone of wet but not necessarily completely saturated soil extending more or less continuously to the 6-foot depth and possibly deeper.

The four hilly-land heavy clay sites at Ecclesville (2), New Grant and Marper (*Category* 4; Tables III, V, VI) also showed a tendency to develop perched water-tables which stayed near to the soil surface (except in the last case) during the greater part of the wet season. The zone of wetness approaching saturation extended here also down to or below the 6-foot depth though probably not much deeper. The Talparo Clay forest site at Ecclesville (No. 15), however, was relatively dry below the 4-foot depth.

The calcareous clay sites at New Grant, Marper and Brasso Venado (*Category* 5; Tables III, V) characteristically developed only narrow zones of wetness whose upper surface (the perched water-table) coincided with ground level for most of the wet season. The calcareous material or parent marl below the 2 to 5 foot depth at these three sites was dry practically the whole year round apparently because of the low infiltrability of the soil surface, the high angle of slope and the low degree of non-capillary porosity of the upper soil, particularly after the cracks had closed through the swelling of the moistened clay during the early part of the wet season.

Finally, the two non-calcareous clay sites at Brasso Venado (*Category* 6; Table VI) showed no water-tables at all; they were very dry throughout the year because of the operation of the same factors as applied in the soil of the last category, exaggerated by a still lower degree of non-capillary porosity in the upper soil.

(IX) Summary

(1) This article describes the results obtained by periodically measuring the *moisture profile* at 17 sites representing 8 different soil-types under forest or cacao in Trinidad. The measurements of gross soil moisture content were made at arbitrary depths down to 6-feet, each site being sampled once every two months during a total period of 14 months.

(2) Porosity characteristics of each soil profile were separately determined on constant volume borer samples procured during wet weather after the moisture sampling had been concluded. The amount of infill of the soil pore-spaces (volume per cent.) could then be calculated from the gross soil moisture values, so that the *free air space* (volume per cent.) could be determined. The results obtained are presented in five tables, each referring to a different drainage category.

(3) The 17 sites are briefly described and laboratory data are tabulated to illustrate their main features.

(4) The main results obtained are:—

(*a*) Three free-draining sandy soils showed adequate or excessive aeration down to full profile depth on every sampling occasion, but they were deficient in water throughout.

(*b*) Two calcareous silty soils having partially-impeded drainage, though possessing high infiltrability, filled up rapidly with water during rains but emptied equally rapidly during dry spells.

(*c*) Two other similar but more clayey silts showed more restricted penetration.

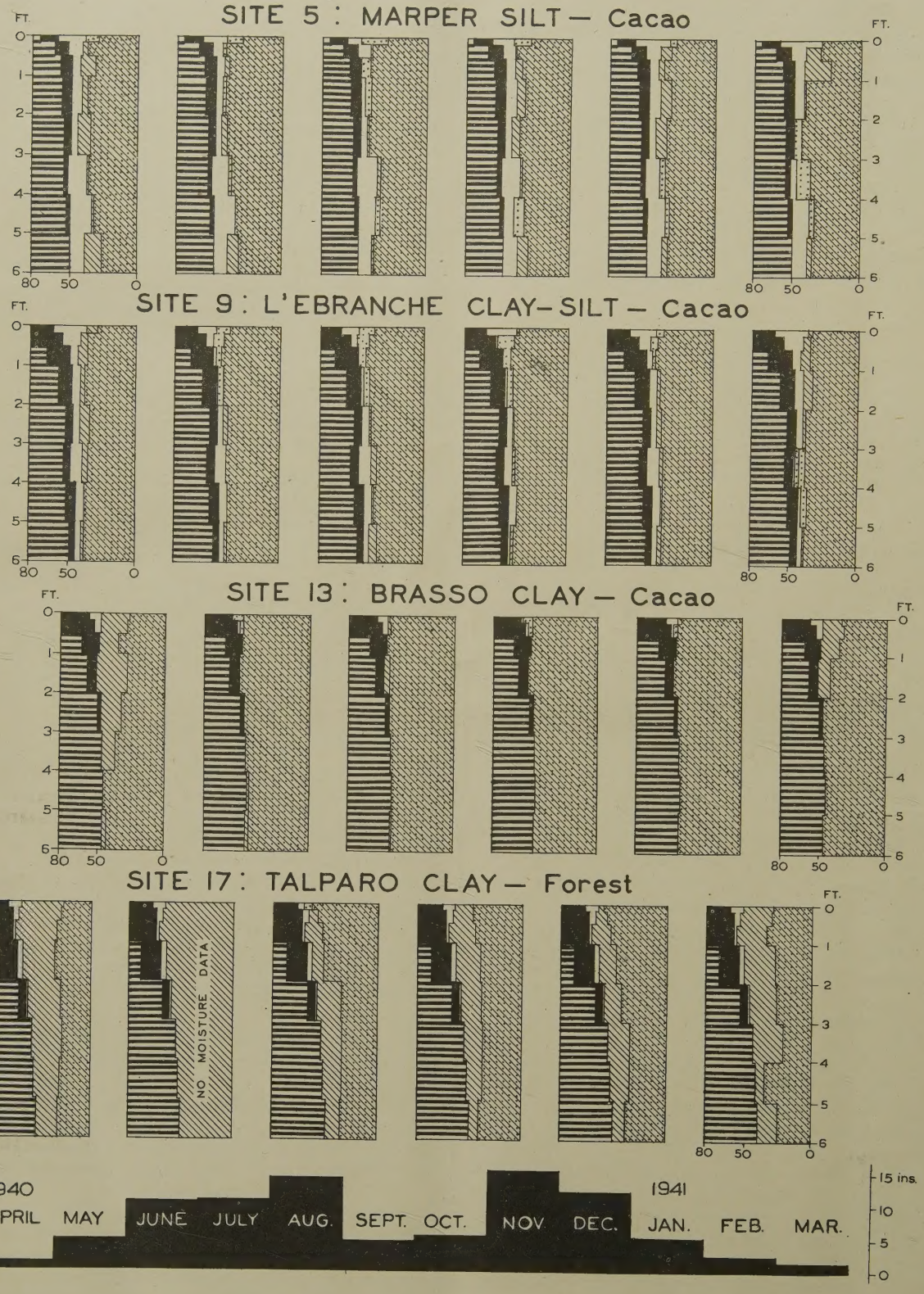
(*d*) Three non-calcareous alluvial silty-clay soils having partially impeded drainage, chiefly because of low relief, showed adequate aeration only in the shallow surface layer of decaying litter and crumb soil, the profile being almost saturated with water throughout the wet season.

(*e*) Three calcareous clay soils having impeded drainage took a long time to fill and water penetration was not deep even at the end of the wet season.

(*f*) Two non-calcareous highly acid heavy clay soils having impeded drainage showed appreciable water penetration because their surface layers were sandy and readily infilterable and the topography not too steep.

(*g*) Two other similar soils showed scarcely any water penetration at all because their surface was infilterable, being devoid of litter and crumb and hard and glazed through erosion, and the topography steep. They consequently support a dry type of forest even though they occur in a belt of high rainfall (about 80 inches a year, with 3 dry season months of 1½ inches rain each). This demonstration of the failure of heavy tropical rainfall to penetrate and to wet certain kinds of clay soils merely because of their unsuitable surface and situation is particularly note-worthy; it affords striking evidence of the magnitude of the

EXAMPLES OF MOISTURE PROFILES



deleterious effects of soil erosion on sloping forest lands that have suffered exposure by indiscriminate tree-felling and by wind and fire damage to crop and soil.

(*h*) These differences in moisture conditions were reflected in the presence or absence of water-tables. In no case was there a true ground-water table, but during periods when the soil was thoroughly wet, perched water-tables developed usually near to the surface although the depth of the zone of wetness below was variable. The two dry clay profiles showed no perched water-tables.

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Explanation of the Diagram

(1) This diagram depicts the moisture status at different depths down to 6 feet at different times of the year for four selected soils out of 17 investigated.

(2) Each profile picture shows the porosity characteristics of the soil. The thick horizontally-shaded area on the left represents the percentage volume of *solid soil matter*; the cross-hatched area on the right represents the percentage volume of the *capillary-pore spaces*, that is, those that can store water but are too small to store air, being mostly micro-reticulate and colloidal. The unshaded area represents the percentage volume of the *non-capillary pore-spaces* that is, those through which water can pass readily under gravity, and which can store air and permit root penetration. The blackened area represents *soil organic matter* content.

(3) The dotted area represents the total percentage volume occupied by *water* at the time of sampling. Thus the percentage volume of the *free air space* (or degree of unsaturation by water), derived by difference between total porosity and volume of water content, can at once be observed. This measures the amount of aeration.

(4) The diagram demonstrates considerable differences between the moisture profiles at the four sites, as follows :—

(*a*) The first (a silt) is comparatively well aerated to full depth throughout the year.

(*b*) The second (an alluvial clay-silt) fills up with water between the surface and the 2-foot depth during wet weather, but empties rapidly when the dry season comes.

(*c*) The third (a calcareous clay) is very badly aerated throughout the wet season, being nearly replete with water to the full depth of the profile. It dries out only slowly later.

(*d*) The last (a non-calcareous clay) is very dry throughout the whole year, water filling a part of the capillary pore-spaces only during rainy weather. This is a typical hilly-land hard red clay whose surface has been damaged by erosion so that it is no longer infilterable.

TERMITE-PROOFING OF TIMBER

Leaflet No. 38 (Forest Prod. Res. Lab., Princes Risborough, Department of Scientific and Industrial Research ; Aug. 1944) is entitled "Termite-Proofing of Timber for Use in the Tropics". This leaflet opens with the statement that manufacturers in Great Britain handling timber, or making furniture, &c., for use in the tropics are often called upon to render wood proof against possible infestation by the termites, and therefore are directly concerned in the injury which these insects may cause. It is admitted that in some countries termites cause the most serious damage, especially to permanent structures, unless precautions have been taken during their planning and construction. "In temporary structures and contents of buildings the risk of severe damage, it is said, is less and it need not be assumed that all materials or articles in which wood is present will at once be attacked and rapidly destroyed by termites when brought into a country in which these insects occur". There may be an element of truth in this, but the experience of many must render them chary of subscribing to this statement, or of taking the risk. Temporary structures may be ruined in a few days if left uninspected.

The leaflet summarized information from a number of publications from certain countries, particularly from those of the Forest Research Institute, Dehra Dun, and the Bureau of Entomology, United States Department of Agriculture, and gives a brief account of how termite damage takes place ; and also how it may be prevented. The subject is treated under the headings: habits of termites, prevention of damage, use of timber treated with wood preservatives, use of termite-resistant woods (among those usually available in Great Britain are iroko (*Chlorophera excelsa*), opepe (*Sarcocephalus diderrichii*), Pacific Coast redwood (*Sequoia sempervirens*), teak (*Tectona grandis*). Plywood and fibre or composition boards and termite attack are also dealt with. It is said that treatment against termites will in most cases also prevent destruction of timber through fungal decay.—(Abstracted from *Nature*, Vol. 155, No. 3927, 1945.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Magnesium Deficiency of Fruit Trees

The occurrence of magnesium deficiency of fruit trees growing in the field has been recognized only in recent years. L. Southwick (*Proc. Amer. Soc. Hort. Sci.*, 42, 85 ; 1943) describes a leaf blotch of apples which appears as an edge burn or interveinal necrosis, together with in some varieties a yellow banding or mottling of the leaves, appearing first in the older leaves and associated with a low magnesium content of the leaves, the scorched leaves usually containing less than 0.25 per cent. magnesium. In the same journal D. Roynton, J. C. Cain and O. C. Compton report that seasonal variations in the potash and magnesium content of apple leaves agree with the seasonal differences in the incidence of leaf scorch and leaf blotch respectively. Leaf blotch due to magnesium deficiency may be reduced by soil application of magnesium sulphate, while it is aggravated by chloride of potash dressings (*ibid.*, 42, 95 ; 1943). L. Southwick and J. K. Shaw find that spraying with magnesium sulphate solution (16 lb. per 100 gallon) gave a partial control of the magnesium deficiency leaf blotch, and that most magnesium-containing substances applied to the soil were effective but magnesium limestone was ineffective in curing the trouble.

In the tung (*Aleurites fordii*) magnesium deficiency symptoms again consist of leaf blotches which increase in size at the margin and the development of brown necrotic areas which progress from the margin inwards between the main veins. As with apples, magnesium sulphate as a soil dressing effects a cure but soil applications of potash aggravate the symptoms (M. Drosdoff and A. L. Kenworthy, *ibid.*, 44, 1 ; 1944).—(*Nature* Vol. 155, No. 3927, 1945.)

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Ardil, A New British Synthetic Fibre

British chemists of I.C.I. have evolved a new synthetic fibre which is wool-like, does not shrink, and is not attacked by moths. The material is known as *Ardil* from the fact that the idea was developed and the experimental work carried out at the I.C.I. works at Ardeer—a factory founded by Alfred Nobel. Ardil was ready for development at the beginning of the war, but since then development work has been held up, and no samples are therefore yet available for distribution to the textile trade.

The vegetable protein used in the production of Ardil is obtained from the ground-nut, more commonly known as the peanut or monkey-nut. The protein is simply extracted from ground-nuts with dilute alkali, precipitated, and then made into a spinning solution. This spinning solution is extruded through the very small fine holes of a spinnerette into a coagulating bath and fine filaments are obtained. These can be cut into any required length according to their final purpose. They may be mixed with wool, cotton, or rayon, and yarns may be made on the worsted woollen or cotton systems according to the type of fibre required.

Ardil is a cream-coloured, crimped, resilient fibre which is soft and warm to the touch. It absorbs moisture like wool and has a similar heat of wetting. Ardil possesses felting properties, not like wool and fur which have scales on their surfaces, but because it moulds and " welds " under heat and pressure. Ardil dyes like wool, but is not attacked by moths.

Fabrics have been made purely of Ardil, but its best use is likely to be in combination with wool to manufacture worsteds, woollens, tweeds, and knitted fabrics. Fabrics containing 50 per cent. Ardil are scarcely distinguishable from 100 per cent. wool. It is expected that Ardil will be cheaper than wool and so reduce the price of such fabrics.—(*Journ. Soc. Chem. Indus.*, No. 51, p.438.)

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Sunnhemp Experiments in North Rhodesia

According to the 1942-43 *Ann. Rept.* of the *Agric. Expt. Station*, Salisbury, experiments on methods of utilizing sunnhemp crops for the restoration of soil fertility were commenced in the season 1935-1936. During the season 1940-1941 sunnhemp was sown again to form the third period of treatment. No advantage was gained by composting the top growth of the sunnhemp crop instead of following the usual practice of ploughing it directly into the soil. Neither was there any apparent advantage in growing the sunnhemp on one side of the field and then converting the top growth into compost for application to the adjoining land. The increase in the subsequent yield of maize was proportionate to the amount of humus incorporated in the soil. The 1938-1940 trials indicated that phosphate was more effective on plots which received the heavier dressings of humus, regardless of whether this was applied in the form of green manure or as compost. In confirmation of previous experience, it is suggested that the green-manure crop is able to utilize stores of plant food which, though present in the soil, were not available to the previous crops of maize. After these nutrients have been utilized by the green crop and returned to the land, they become available for the use of succeeding maize crops. Trials with raw rock phosphate applied to maize supported previous results in showing that although slightly larger yields may be obtained from land which receives large applications of raw rock phosphate, the cost of the fertilizer would exceed the value of the extra maize. The ravages of beetles which attack sunnhemp and the high cost of its seed have caused farmers to look for alternative crops to use as green manure. Niger oil seed (*Guizotia abyssinica*) gave promise of being suitable for green manure but presents harvesting difficulties.—(*Soil and Fertilizers*, VII, 4, 1944.)